Deep, Residual Nitrogen Supports Grain Sorghum Yield

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Introduction

Grain sorghum is widely rotated with cotton annually on approximately 1.3 million hectares in Texas and is the second-most important crop grown for feed and bio-fuel feedstock in the United States. Improving management of nitrogen (N) fertilizer for grain sorghum production is necessary from both economic and environmental standpoints and the optimum N rate may vary as the growing season progresses (Forrestal et al., 2012). Applied N in grain sorghum cropping systems is subject to biological interactions and loss through leaching, runoff, and volatilization. Movement of excess residual NO_3-N out of the plant rooting zone represents an economic loss to producers and has negative implications for water quality (Baker and Johnson, 1981), even after decades of time (Sebilo, et al., 2013).

Previous studies in cotton across all production regions of Texas identified high residual NO_3-N concentrations in soil profiles (Hons et al., 2004). Using 15N-enriched fertilizer, Provin et al. (2007) demonstrated that uptake by cotton plants was effective down to a 106 cm soil depth and fertilizer uptake efficiency increased at greater depths as the growing season progressed. Additional information was needed about how effectively Texas-grown grain sorghum could utilize residual soil N below the traditional 15 cm sampling depth.

Objective

Evaluate the ability of grain sorghum to utilize residual soil NO_3-N for contribution to grain yield at 15, 30 and 60 cm soil depths.

Materials & Methods

Grain sorghum hybrids adapted to growing conditions in the Central Blacklands and Upper Gulf Coast regions of Texas were planted on cooperator farms from early to late March. Pre-plant soil samples from each study site were collected to a 1.22 m depth in December to February and submitted for routine nutrient analysis (Plate 1). Establishment of N treatments was based on a representative yield goal for the area and analysis of residual NO_3-N in sample cores to 15 (current University approach), 30, and 61 cm depths. Nitrate-N was determined in 1M KCl extract via Cd-Reduction.

Experimental design for each study was a randomized complete block with experimental units replicated five times. Plots were four rows wide with intra-row spacing of 0.97 m and length of 21.3 to 25.9 m.

Liquid urea ammonium nitrate (UAN, 32-0-0) was used in all studies and N treatments were side-dress banded soon after emergence or before planting. All plots received subsurface, side-dress banded P, K and Zn at rates recommended by soil tests.

Plate 1. Giddings hydraulic soil probe and ground-driven, liquid fertilizer applicator used in all studies.

Depending on the site-year, grain yield was determined by hand harvesting 3.05 m or machine harvesting the entire plot length from each of two center rows per plot (Plate 2). Statistical significance of main effects was determined by analysis of variance using SAS Proc Mixed and means separated with t-tests according to the PDIFF option within LS Means statements.

Results & Discussion

Rainfall amounts varied greatly among locations and years. Below normal rainfall and above normal temperatures were experienced at study sites in 2008 and 2009 (data not shown). Contrastingly, seasonal rainfall totals ranged from 85 to 130 percent of the long-term average across study sites in 2010 and 2012. Extremely-dry growing conditions persisted in 2011 with seasonal rainfall ranging from 16 to 35 percent of normal.

Cumulative amounts of residual soil NO_3-N ranged from 27 to 230 kg/ha across study environments in the Central Blacklands and Upper Gulf Coast of Texas (Table 1). Based on annual surveys of local, retail fertilizer pricing, residual soil NO_3-N to 61 cm was valued from 6 to 78 USD/ha across study sites. In 84 percent of study sites, the greatest amounts of residual NO_3-N was measured within the 30 to 61 cm soil depth. It was speculated that there had been downward movement of N from applied N fertilizer in previous seasons, particularly following seasons with below average rainfall and reduced crop growth.

Table 1. Mean amounts and value of pre-plant, residual NO_3-N at incremental soil depths and site-years for studies in the Central Blacklands and Upper Gulf Coast of Texas, 2008-2012.

Region, Site-Year	Cumulative Amount and Value of Residual Soil NO_3-N 0 to 15 cm	15 to 30 cm	30 to 61 cm	0 to 61 cm	Value[†]
	-------------------------kg N/ha			------------------------	USD/ha
Central Blacklands					
Collin 2008	10	7	16	32	7
Hill 2008	12	13	14	40	9
Williamson 2008	2	7	18	27	6
Fannin 2009	34	31	51	116	27
Hill 2009	36	25	41	102	23
Williamson 2009	32	7	13	53	12
Hill 2010	9	7	27	43	10
Williamson 2010	3	12	29	44	10
Guadalupe 2012	13	65	40	118	40
Williamson 2012	13	18	58	89	30
Upper Gulf Coast					
Calhoun 2008	7	8	9	24	6
Victoria 2009	27	29	31	87	43
Nueces1 2010	3	22	105	130	30
Nueces2 2010	3	20	155	178	41
Victoria 2010	6	7	20	33	8
Wharton 2010	6	7	36	49	11
Nueces 2011	8	11	18	37	10
Victoria 2011	6	11	16	33	9
Victoria 2012	52	140	38	230	78

[†] Based on surveys of retail fertilizer pricing for that year and location.

The site-year by N rate interaction for grain yield was highly significant, thus each site-year was analyzed separately ($p < 0.0001$; df = 59). Thus, grain sorghum yield responded to addition of N fertilizer in 7 of 19 site-years (Table 2).

Compared to sorghum that received a crop goal amount of N fertilizer, yield of sorghum in plots with reduced rates of N based on soil test NO_3-N to 61 or 30 cm depths was not statistically different in each of 19 studies. These findings were similar to results from studies in corn, conducted in the Central Blacklands and Upper Gulf Coast regions of Texas (Coker et al., 2008; Coker et al., 2014).

Table 2. Effect of crediting nitrogen fertilizer rate according to pre-plant, residual NO_3-N at incremental soil depths on grain sorghum yield throughout the Central Blacklands and Upper Gulf Coast of Texas, 2008-2012.

Region, Site-Year	Grain Yield According to Crop Goal	Soil NO_3-N to 15 cm	Soil NO_3-N to 30 cm	Soil NO_3-N to 61 cm	Control[†]
	--		kg/ha		-------------------------------------
Central Blacklands					
Collin 2008	4388 a[‡]	4051 a	4119 a	4219 a	2536 b
Hill 2008	4557 a	4511 a	4545 a	4450 a	4235 b
Williamson 2008	5734 a	-[§]	5658 a	5447 a	4306 b
Fannin 2009	4953	5106	4767	4409	4750
Hill 2009	4254	4648	4392	4400	4466
Williamson 2009	992	1245	-	1177	1050
Hill 2010	5926	-	5930	5464	5476
Williamson 2010	5203	-	5161	5404	5334
Guadalupe 2012	6585	7016	6661	6614	6614
Williamson 2012	6409	6134	5966	5750	6052
Upper Gulf Coast					
Calhoun 2008	5460 a	5122 a	5116 a	5171 a	3096 b
Victoria 2009	4701 a	4334 ab	4670 a	3910 b	3807 b
Nueces1 2010	4340	-	4622	5194	4832
Nueces2 2010	5505	-	5691	5998	5759
Victoria 2010	5652 a	-	5292 ab	4929 b	1432 c
Wharton 2010	6024 a	-	5724 a	5714 a	3929 b
Nueces 2011	4905	-	5294	4597	5132
Victoria 2011	3842	-	4430	4217	3616
Victoria 2012	6251	6232	-	-	5718

[†] No additional nitrogen added.

[‡] Within rows, means followed by different letters were significantly different according to the ANOVA F Test and Differences of Least Squares Means *t* test (P≤0.05).

[§] Amount of residual N at interval soil depth was not sufficient or in excess of crop need to establish a treatment.

The site-year by N rate interaction for grain test weight was also significant, thus each site-year was analyzed separately ($p < 0.0066$; df = 52) with results presented in Table 3.

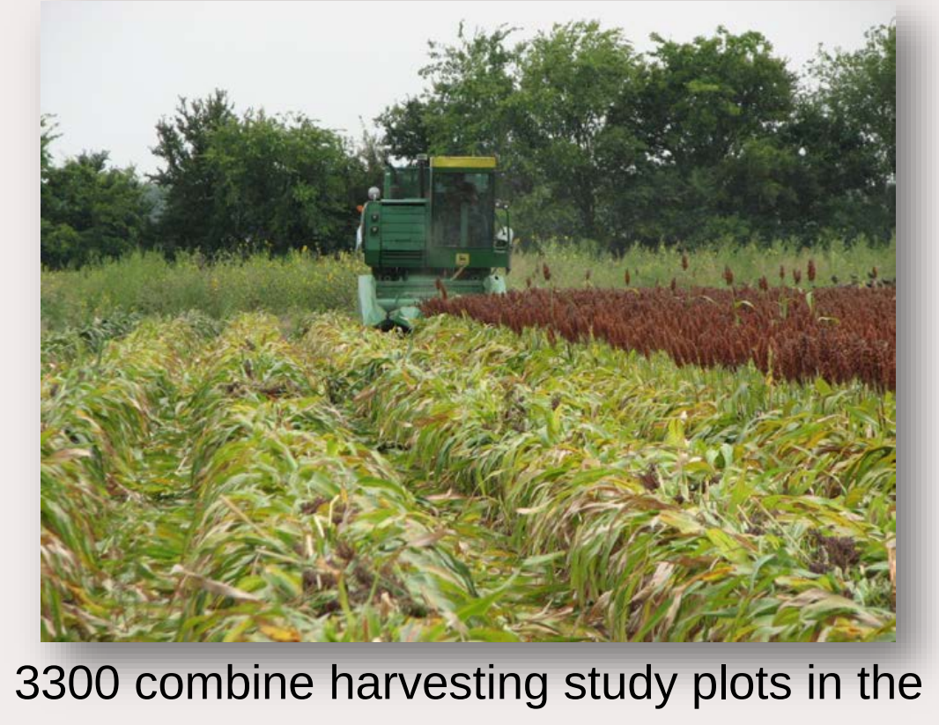

Plate 2. John Deere 3300 combine harvesting study plots in the Central Blacklands.

Excepting Victoria 2009, sorghum test weights from plots with N fertilizer rates reduced according to residual NO_3-N to 61 cm were not different compared to those with N fertilizer applied according to crop goal. Statistical differences in grain test weights of control plots compared to those that received additional N were not consistent across site years.

Table 3. Effect of crediting nitrogen fertilizer rate according to pre-plant, residual NO_3-N at incremental soil depths on grain sorghum test weight. Central Blacklands and Upper Gulf Coast of Texas, 2008-2012.

Region, Site-Year	Grain Test Weights According to Crop Goal	Soil NO_3-N to 15 cm	Soil NO_3-N to 30 cm	Soil NO_3-N to 61 cm	Control[†]
	------------------------------------		kg/m^3		------------------------------------
Central Blacklands					
Collin 2008	784	753	784	762	776
Williamson 2008	797 ab[‡]	-[§]	798 a	792 bc	788 c
Fannin 2009	705	712	708	700	708
Hill 2009	726	723	743	707	716
Hill 2010	650	-	644	633	623
Williamson 2010	759	-	765	774	766
Guadalupe 2012	638	624	629	655	655
Williamson 2012	676	689	690	692	671
Upper Gulf Coast					
Calhoun 2008	708	695	695	669	682
Victoria 2009	783 a	723 b	732 b	726 b	753 ab
Nueces1 2010	606	-	617	619	628
Nueces2 2010	683	-	694	686	686
Victoria 2010	669	-	682	669	672
Wharton 2010	711 b	-	709 b	711 b	725 a
Nueces 2011	678	-	692	678	683
Victoria 2011	718 ab	-	745 a	692 abc	665 bc
Victoria 2012	756	750	-	-	753

[†] No additional nitrogen added.

[‡] Within rows, means followed by different letters were significantly different according to the ANOVA F Test and Differences of Least Squares Means *t* test (P≤0.05).

[§] Amount of residual N at interval soil depth was not sufficient or in excess of crop need to establish a treatment.

Summary

- ✓ Reducing N fertilizer applications for grain sorghum based on residual soil NO_3-N to 61 cm had no effect on grain sorghum yield across 89 percent of site-years and test weights were largely unaffected across environments.
- ✓ Production economics can be improved and potential environmental impacts on water quality lessened by management of deep profile, soil N in the Central Texas Blacklands and Upper Gulf Coast fields planted to grain sorghum.

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